



Remote sensing of wintertime ground cover on agricultural fields: cover crop performance for Chesapeake Bay

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Research Approach

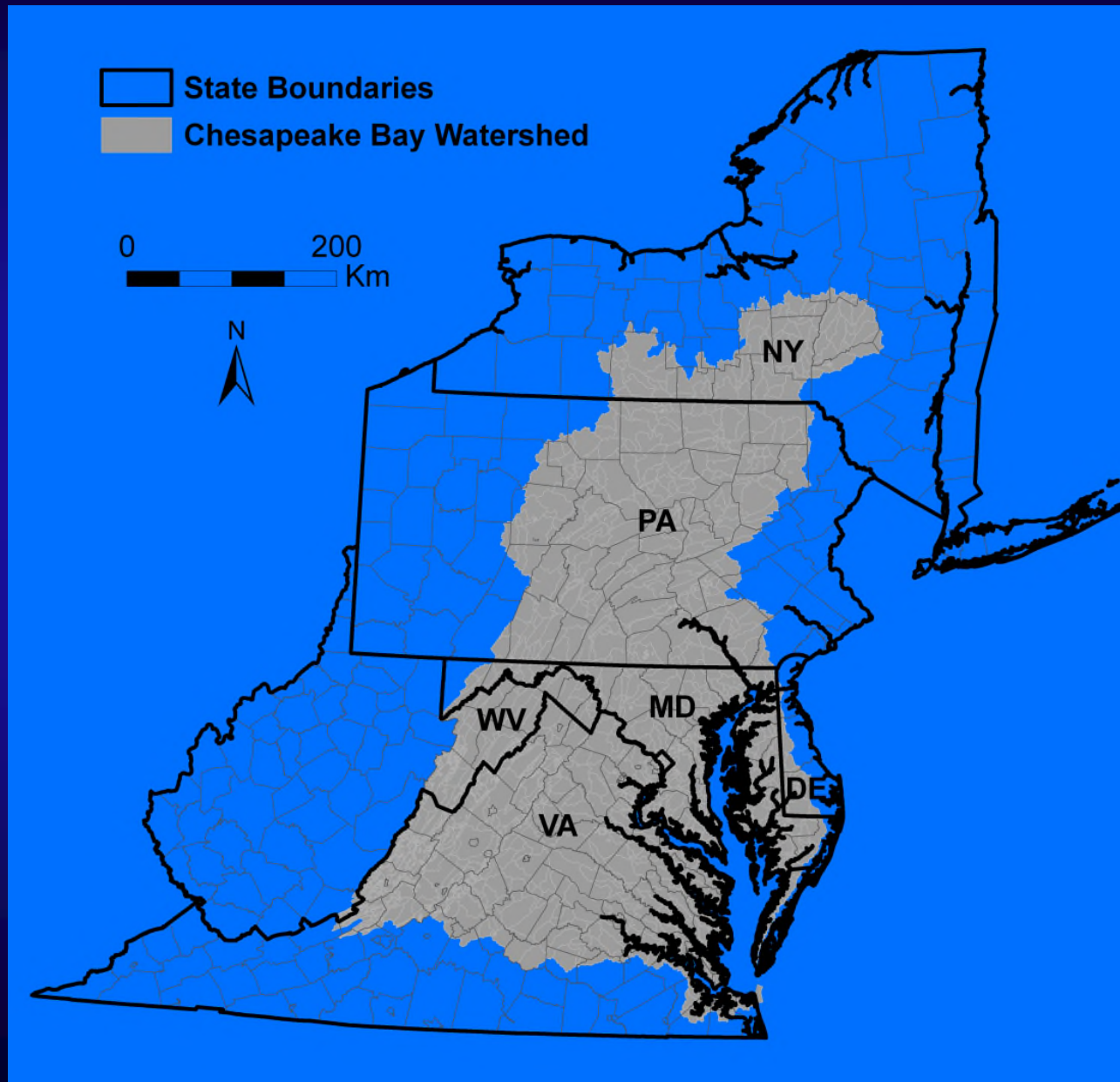
- The research investigates the linkage between agricultural land use, conservation practices, and water quality
- Effective implementation of agricultural conservation practices is critical to the reduction of nutrient and sediment loading to the Chesapeake Bay
- We are developing geospatial tool kits to measure the effects of conservation practice implementation, with a focus on winter cover crops
- Data integration approach matches satellite measurements of winter biomass (Landsat, SPOT) with site-specific knowledge of agricultural conservation practices
- Collaborative approach, working within the context of the USGS Chesapeake Bay Science Plan and the Executive Order for Chesapeake Bay protection and Restoration

Collaborators:

- **United States Department of Agriculture (USDA) Agricultural Research Service - Hydrology and Remote Sensing Laboratory**
- **University of Maryland Geography Department**
- **Maryland Department of Agriculture**
- **Soil Conservation Districts, Farmers**



Chesapeake Bay



Remote sensing of winter cover crop performance

Winter cover crops for water quality

- Improve soil aggregate stability, biological activity
- Alleviate compaction, increase trafficability
- Provide groundcover and reduce soil erosion
- Help to manage weeds
- Produce useful products (grain silage, emergency forage, straw harvest, bioenergy)
- Improve nutrient management

*** REDUCE NITROGEN AND SEDIMENT LOSS ***

An aerial photograph of a vast agricultural field, likely corn, showing distinct rows of young green plants. The plants are densely packed in some areas and more sparse in others, illustrating variability in growth. In the far background, a large center pivot irrigation system is visible, with its long metal arms stretching across the horizon under a clear sky.

On-farm performance is variable













Nitrogen capture by winter cover crops can reduce nutrient and sediment loss to the Chesapeake Bay.

But performance is variable.

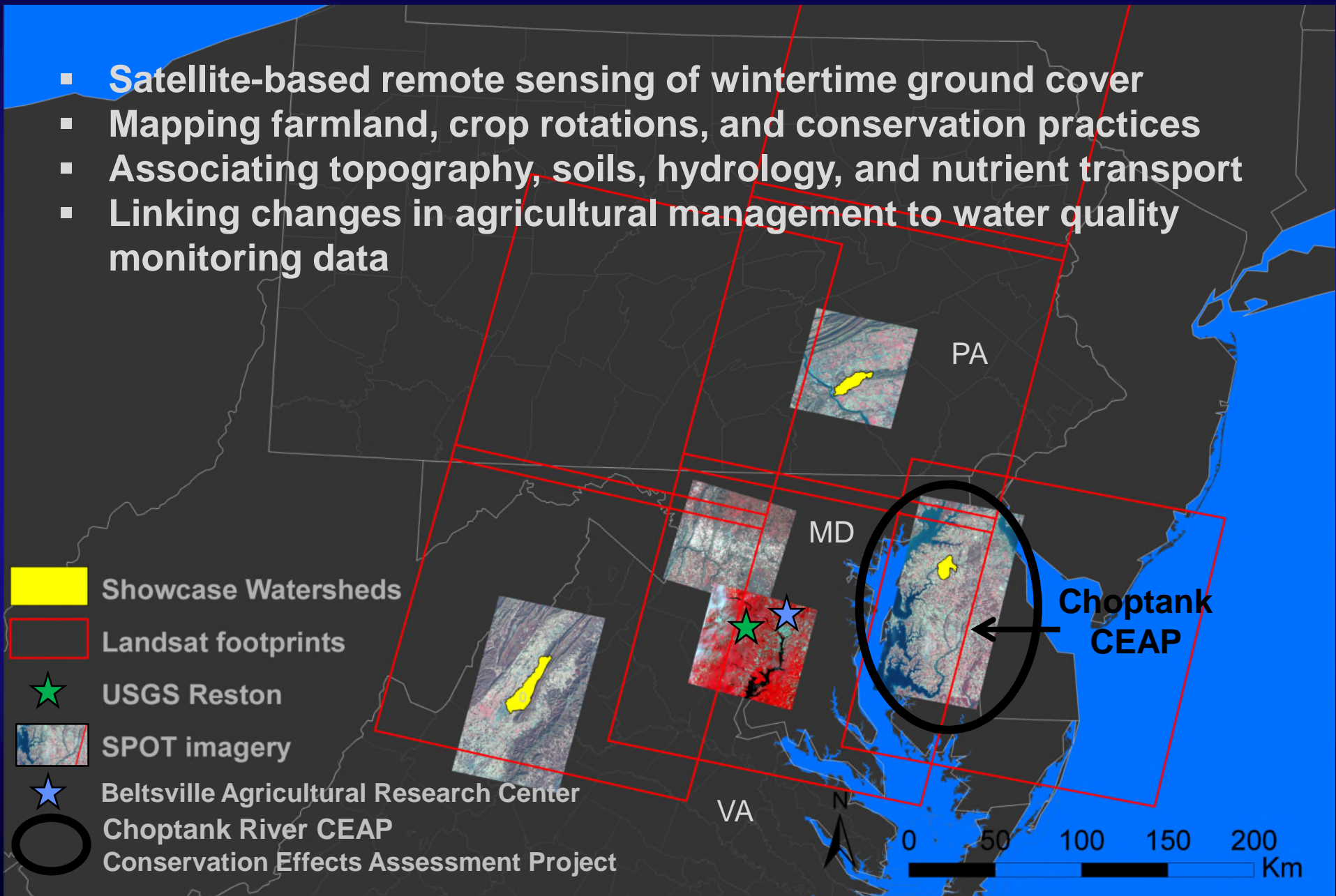
How much is captured?

And how do agronomic practices compare?

These questions can be answered by combining farm-program data records with satellite remote sensing and on-farm sampling

2014 study areas

- Satellite-based remote sensing of wintertime ground cover
- Mapping farmland, crop rotations, and conservation practices
- Associating topography, soils, hydrology, and nutrient transport
- Linking changes in agricultural management to water quality monitoring data



Remote sensing of winter cover crop performance

- **Combining spatially accurate satellite imagery analysis with site-specific knowledge of agricultural land use management**
- **Estimating biomass and nutrient uptake on fields enrolled in the Maryland cover crop cost-share program**
- **Working with the Maryland Department of Agriculture (MDA) to implement statewide geospatial management of cover crop cost-share programs – web enabled beta test in fall 2014**
- **Providing winter groundcover analysis in MD, PA, NY**

Data:

- **On-farm sampling of plants and soils: 1200+ samples over 7 years**
- **Wintertime vegetation measurement using Landsat and SPOT**
- **Geospatial toolkits have been programmed to assist analysis**

Strategy

- Working directly with Soil Conservation Districts
- Protecting privacy of farm conservation data to meet Farm Bill (Section 1619) and state requirements
- Support adaptive management



MDA provides cost-share program farm enrollment data

- Field location
- Species (rye, barley, wheat, brassicas)
- Planting method (drilled, broadcast, aerial)
- Planting date (Mid-September to Nov 5th)
- Previous crop (corn grain, corn silage, soy)

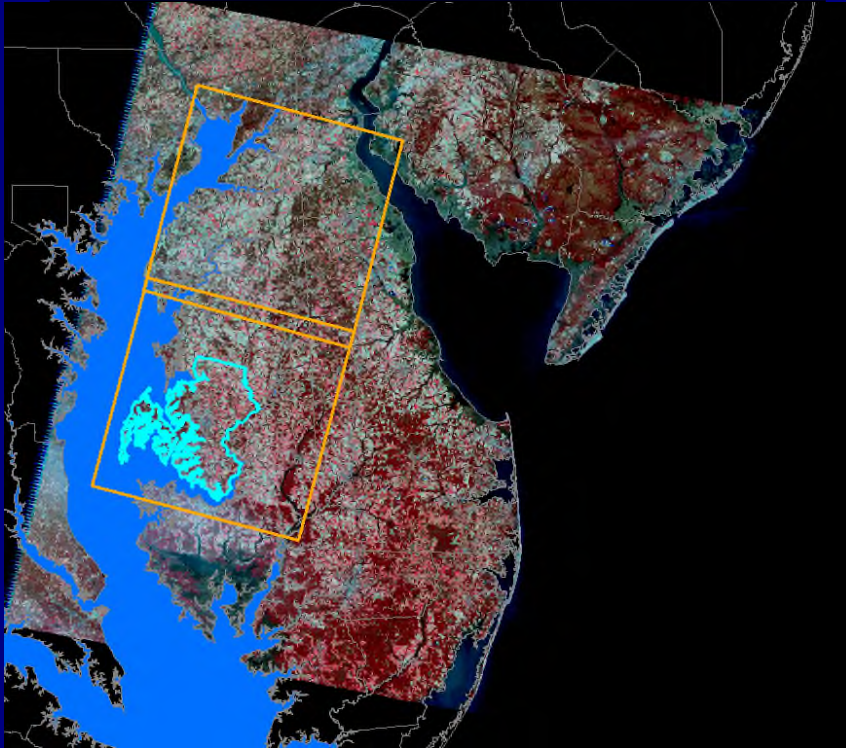
This allows us to use remotely sensed measures of aboveground biomass as a *response variable*

Satellite Imagery

Landsat and SPOT

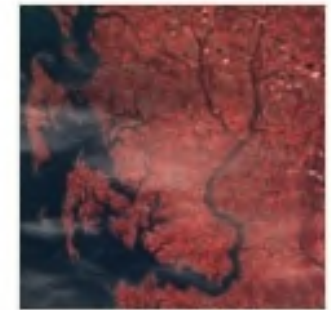
Landsat5 Imagery

March 8th, 2011



2010-11-29

46252721011291543402IO...



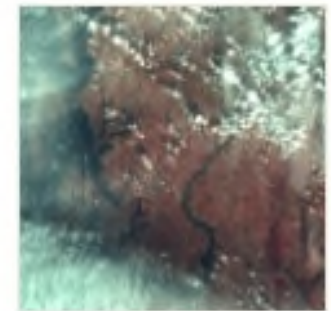
2010-12-04

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2011-1-6

56252721101061606141JO...



2011-1-07

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- Sometimes cloudy, sometimes clear
- Each image is a snapshot in time
- Fairly accurate mapping of agricultural vegetation
- We are most interested in mid-winter imagery

**A collaborating farm
Talbot County, Maryland**

Jan 6th, 2011 SPOT4 satellite imagery

MD ChopS Jan6th2011 1101061606141J05625272_1GST_sh_toa.tif

**Overlap with winter cover crop
farm enrollment data records**

● CC_Field Sampling Locations

Cover Crop Species

	Wheat
	Rye
	Barley
	Radish
	Canola
	Spring Oat

Barley
2.5 bu/ha
No-till drill
9/14/2010
after Corn

Barley
2.5 bu/ha
No-till drill
9/17/2010
after Corn

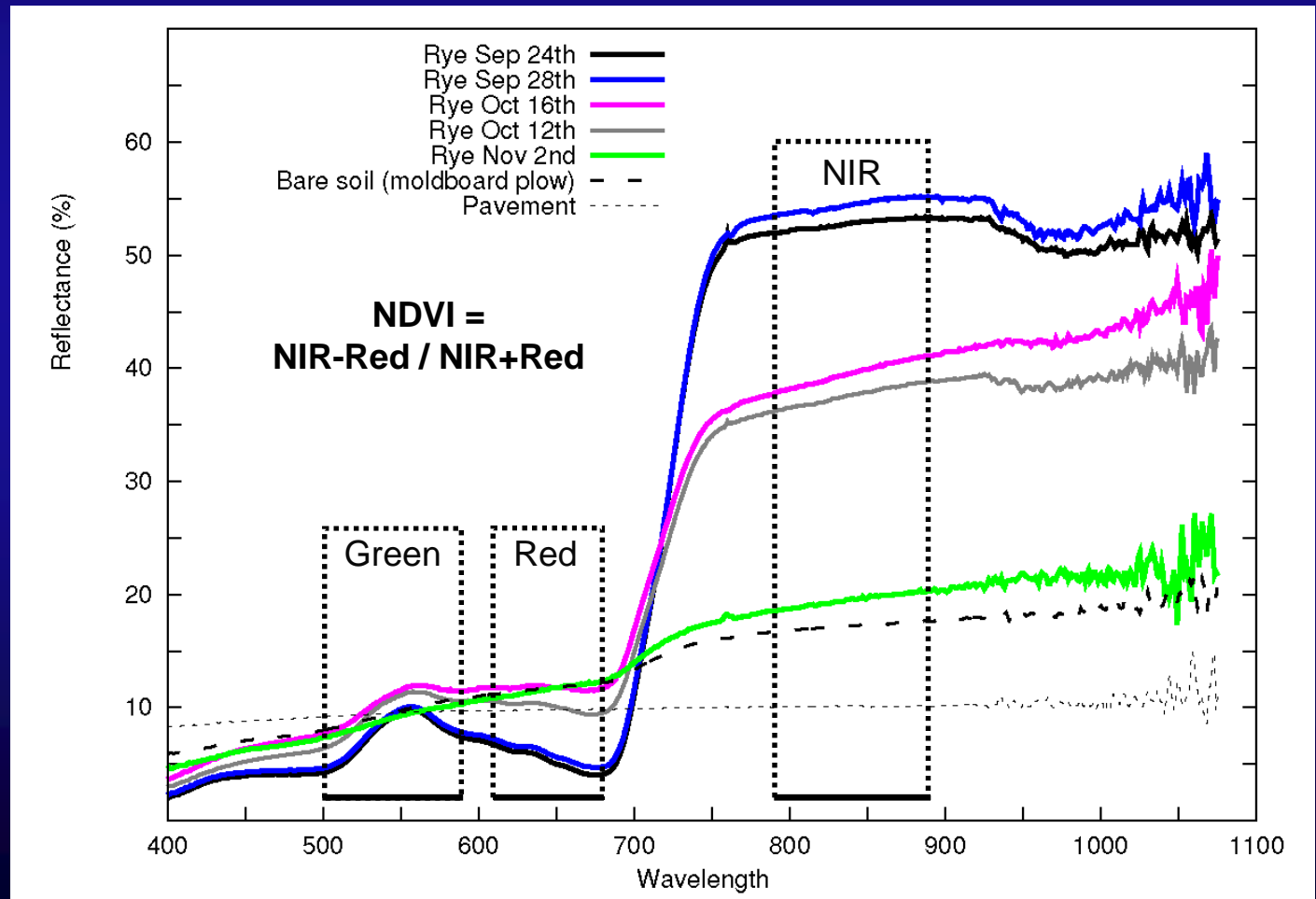
**This normally private information
was released to the public by the
collaborating farmer**



0 0.4 0.8 1.2 1.6
Km

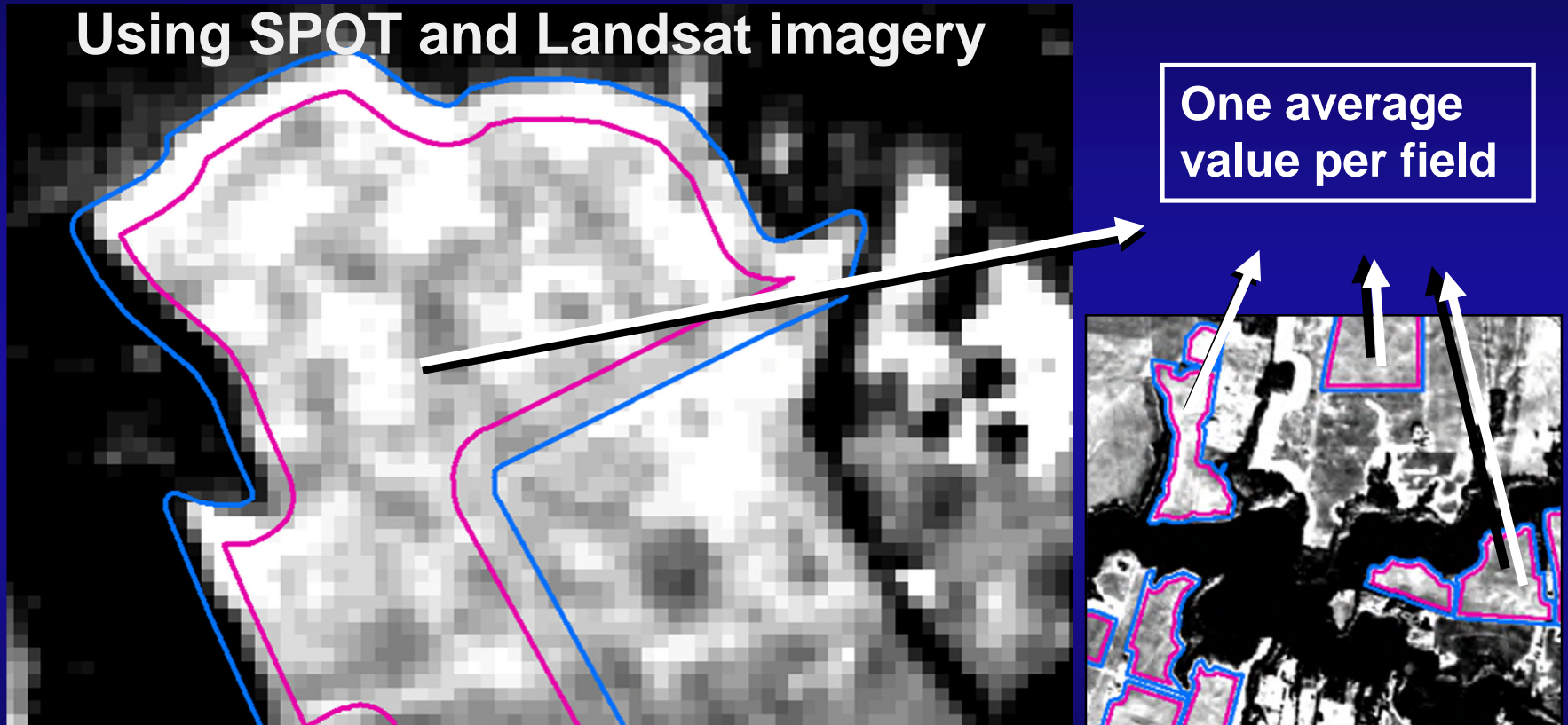
Calculation of wintertime greenness

- Multispectral vegetation indices such as NDVI or MSAVI applied to satellite imagery surface reflectance



Calculate vegetation index for each cover crop field

Using SPOT and Landsat imagery



One average
value per field

Use calibrations to translate vegetation indices into performance measures:

- Biomass
- N content
- % ground cover

On-farm field sampling for calibration



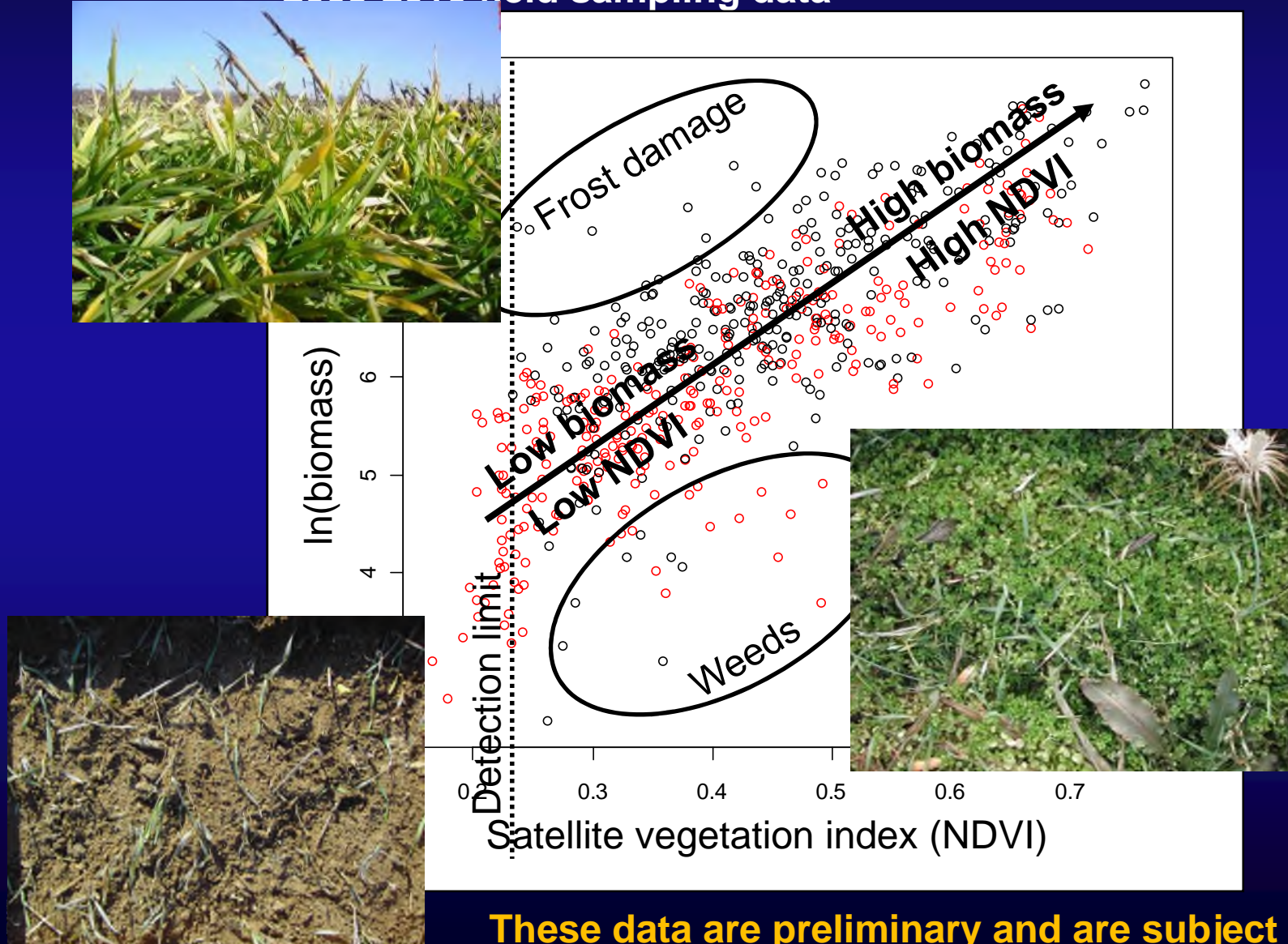
- Aboveground biomass
- Plant N, chlorophyll
- Surface reflectance
- % cover (RGB photos)
- Soil nitrate content
- ~ 30 fields per season
 - Dec/Jan (fall)
 - Mar/Apr (spring)
- ~ 1200 samples in 7 yrs



Extract vegetation index (e.g. NDVI) for each sampling location from satellite imagery

Use satellite imagery to predict biomass

2005-2010 field sampling data



These data are preliminary and are subject to revision

**A collaborating farm
Talbot County, Maryland**

Jan 6th, 2011 SPOT4 satellite imagery

MD ChopS Jan6th2011 1101061606141J05625272_1GST_sh_toa.tif

● CC_Field Sampling Locations

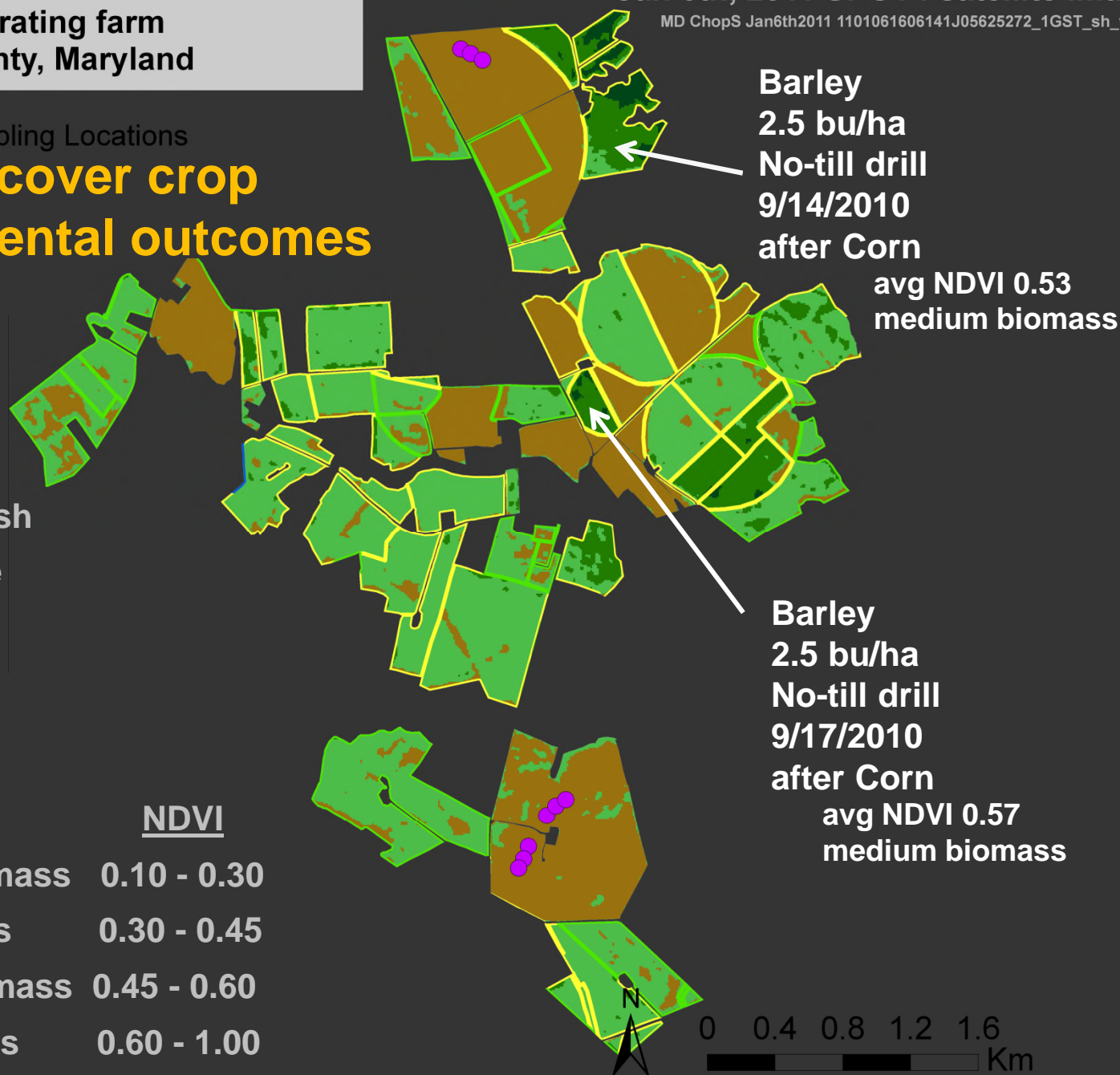
**Map cover crop
environmental outcomes**

Species

- Wheat
- Rye
- Barley
- Forage Radish
- Canola/Rape
- Spring Oats

NDVI

- | | | |
|--|-----------------|-------------|
| | Minimal biomass | 0.10 - 0.30 |
| | Low biomass | 0.30 - 0.45 |
| | Medium biomass | 0.45 - 0.60 |
| | High biomass | 0.60 - 1.00 |



**Barley
2.5 bu/ha
No-till drill
9/14/2010
after Corn**

avg NDVI 0.53
medium biomass

**Barley
2.5 bu/ha
No-till drill
9/17/2010
after Corn**

avg NDVI 0.57
medium biomass

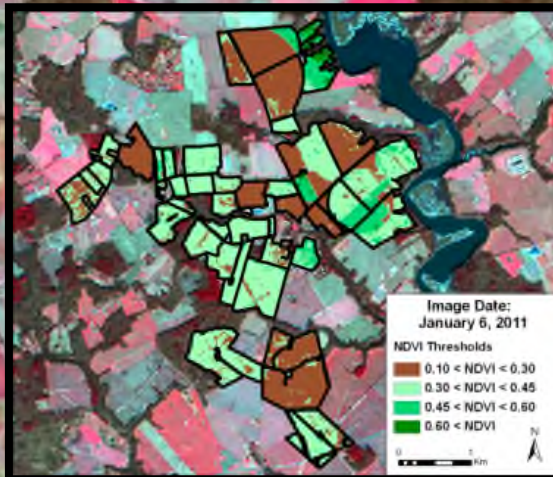
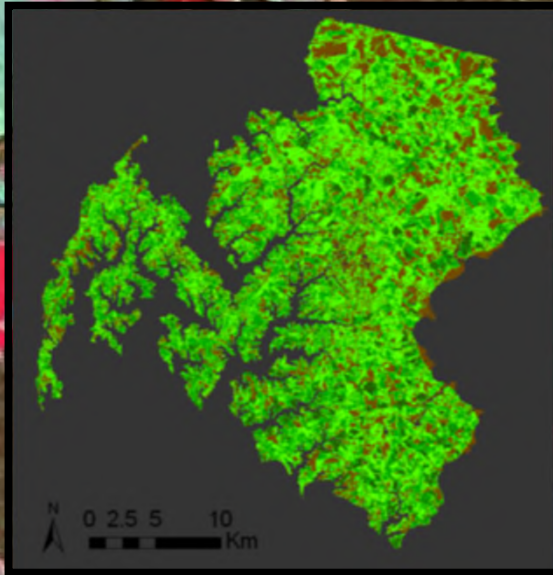
0 0.4 0.8 1.2 1.6
Km

Adaptive Management of Winter Cover Crops

Produce county/watershed reports for local partners

Provide field-specific information to farmers

Target low-productivity fields for site visits

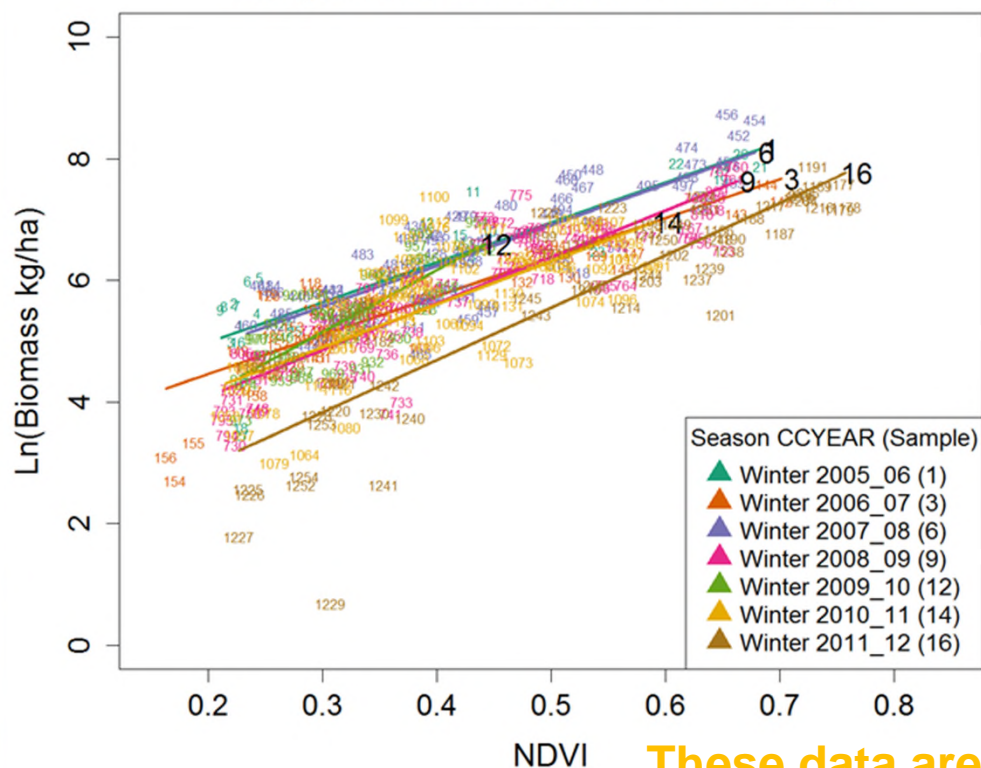


Remote sensing of winter cover crop performance

Forthcoming manuscript I (2014):

- Remote sensing of cover crop performance: calibration between satellite imagery and on-farm biomass measurements (Hively et. al., for Journal of Applied Remote Sensing)

Simple Model Fits, Winter All Crops



SPOT top of atmosphere (TOA) data shows similar slopes with date-to-date variability in intercept

Now working to convert SPOT to surface reflectance (SR) using FLAASH

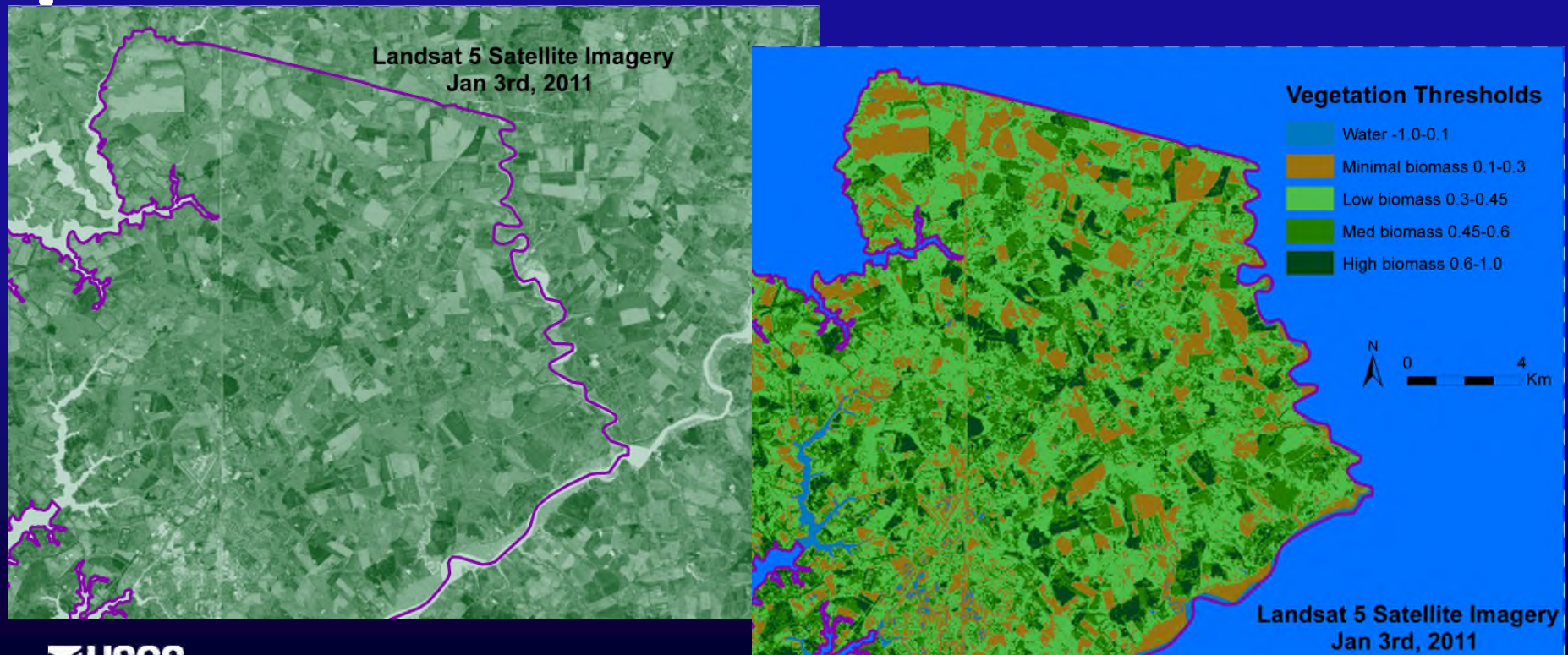
Comparison will be made with Landsat TOA and Landsat SR provided by EROS Data Center

These data are preliminary and are subject to revision

Remote sensing of winter cover crop performance

Forthcoming manuscript II (2015):

- Six years of cover crop performance in Talbot County, MD, 2008-2013 (Hively et. al., invited paper for special issue on cover crops in Journal of Soil and Water Conservation)



What factors affect cover crop success?



Planting date



Species choice



Wheat



 USGS

Rye



Barley

Planting method



previous crop



Analysis (example data for Jan 6th, 2011)

Satellite
+ NCDL
+ Records

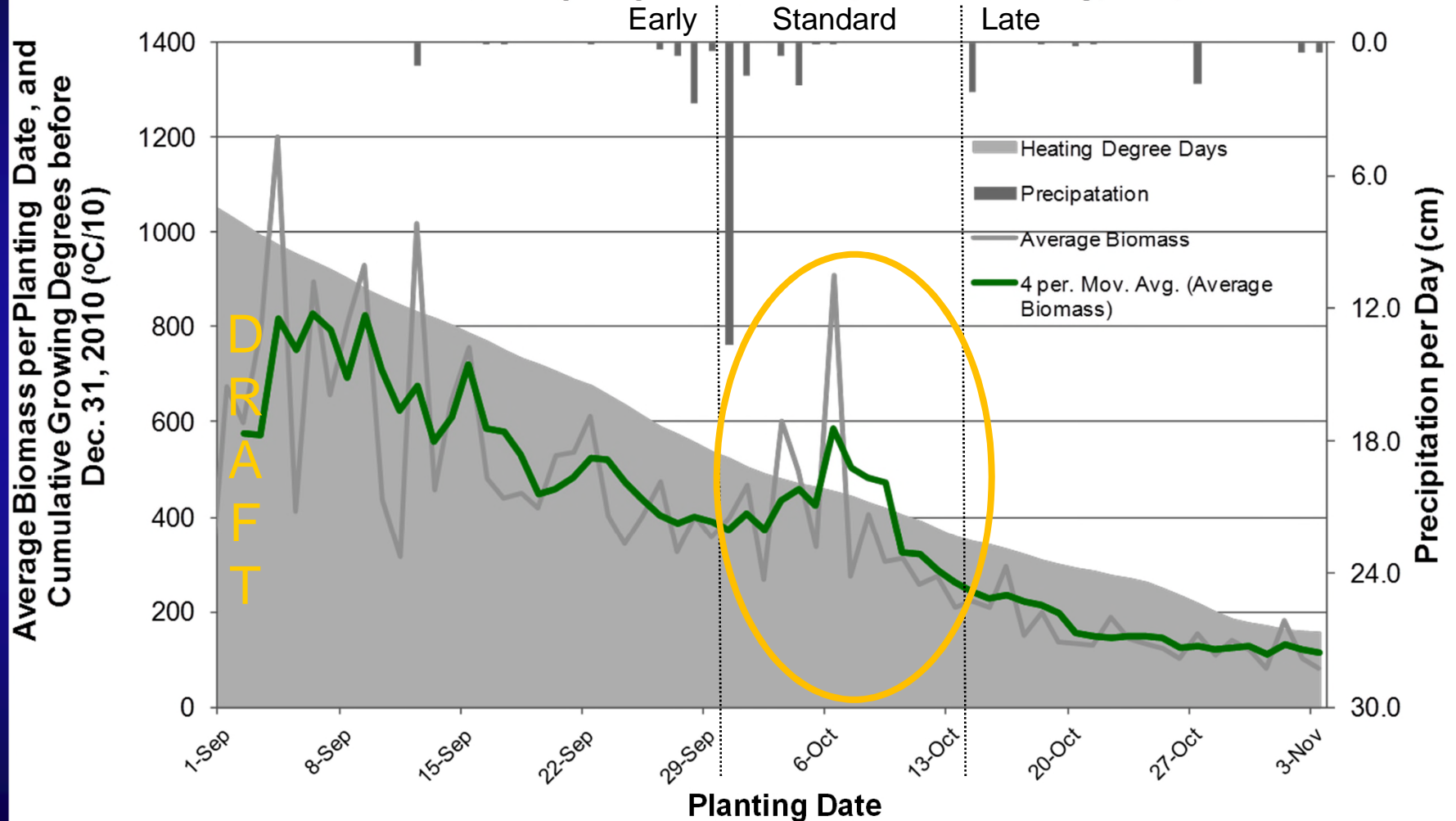
	Cover Crop Enrolled Fields		Observed NDVI	Predicted Biomass	Predicted N Content
	#	ha	NDVI	kg ha ⁻¹	kg ha ⁻¹
Species					
Wheat	1726	15039	0.36	224	4.5
Rye	123	878	0.35	226	4.5
Barley	236	2761	0.36	248	5.0
Planting Date					
Early < Oct 1	1050	8492	0.38	279	5.6
Standard Oct 1-15	630	6183	0.36	206	4.1
Late > Oct15	487	4713	0.30	128	2.6
Planting method					
Aerial	242	1404	0.31	139	2.8
Broadcast	100	651	0.32	155	3.1
Broadcast Stalk Chop	38	185	0.34	195	3.9
Broadcast Light Disk	659	5524	0.36	255	5.1
Conventional Drill	50	702	0.40	272	5.4
No-Till Drill	1078	10922	0.36	230	4.6

D
R
A
F
T

Assuming 2% N content for all cover crops. Data for use as example only.
These data are preliminary and are subject to revision. They are being
provided to meet the need for timely 'best science' information.

Linking performance to climate

Winter Cover Crop Implementation, Talbot County, MD, 2010-11

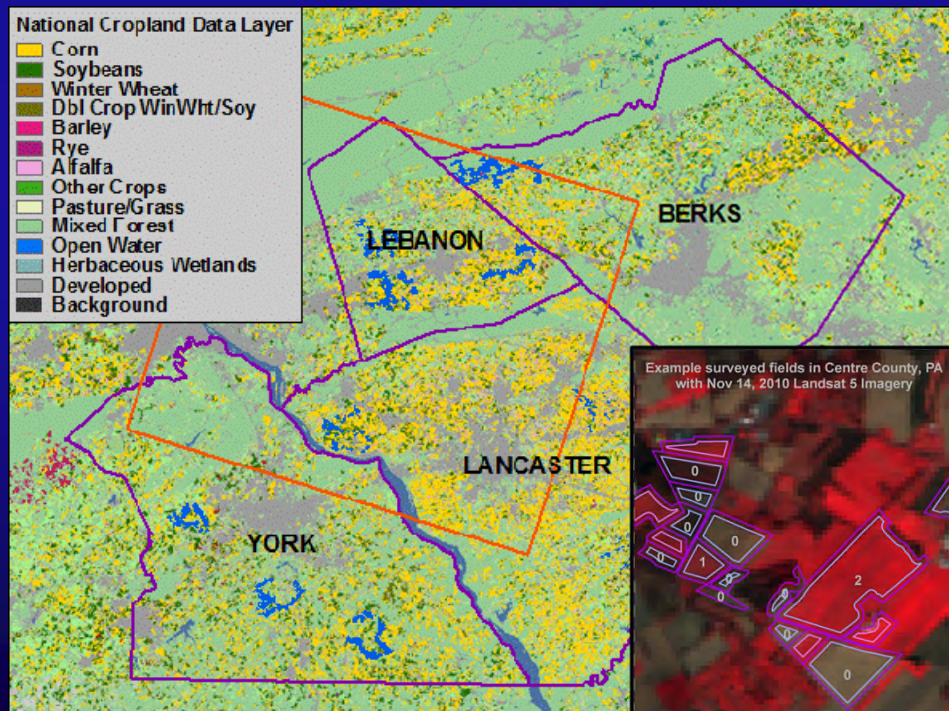


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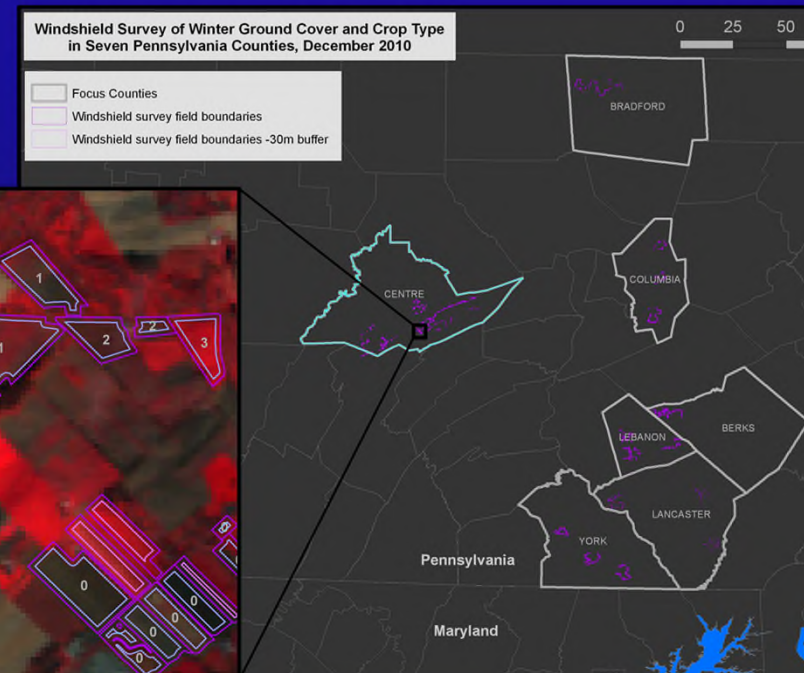
Remote sensing of winter cover crop performance

Forthcoming manuscript III (2014):

- Remote sensing to monitor cover crop adoption in southeastern Pennsylvania (Hively, Duiker, and McCarty, for Journal of Soil and Water Conservation)

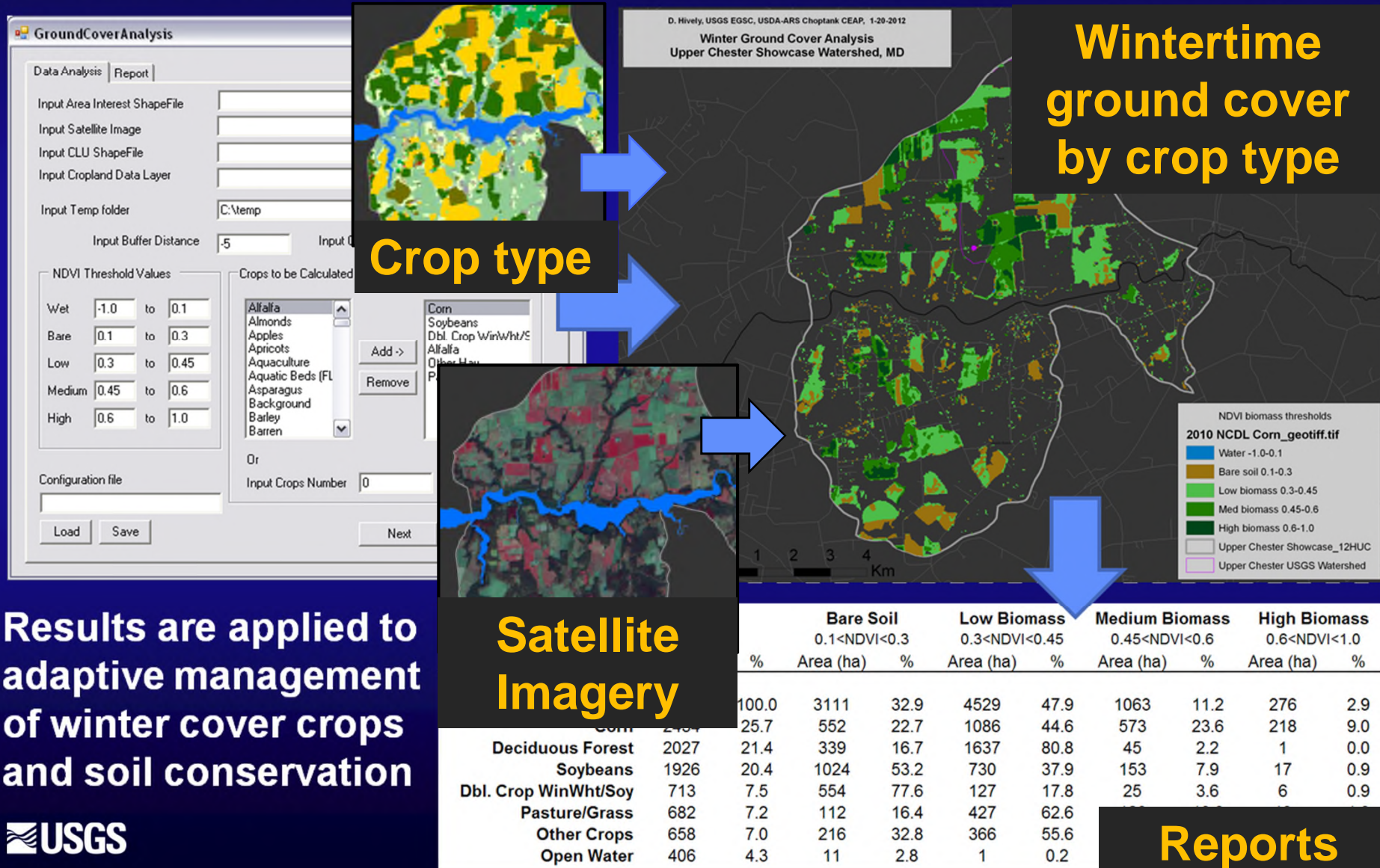


- Landsat, SPOT
- National Cropland Data Layer



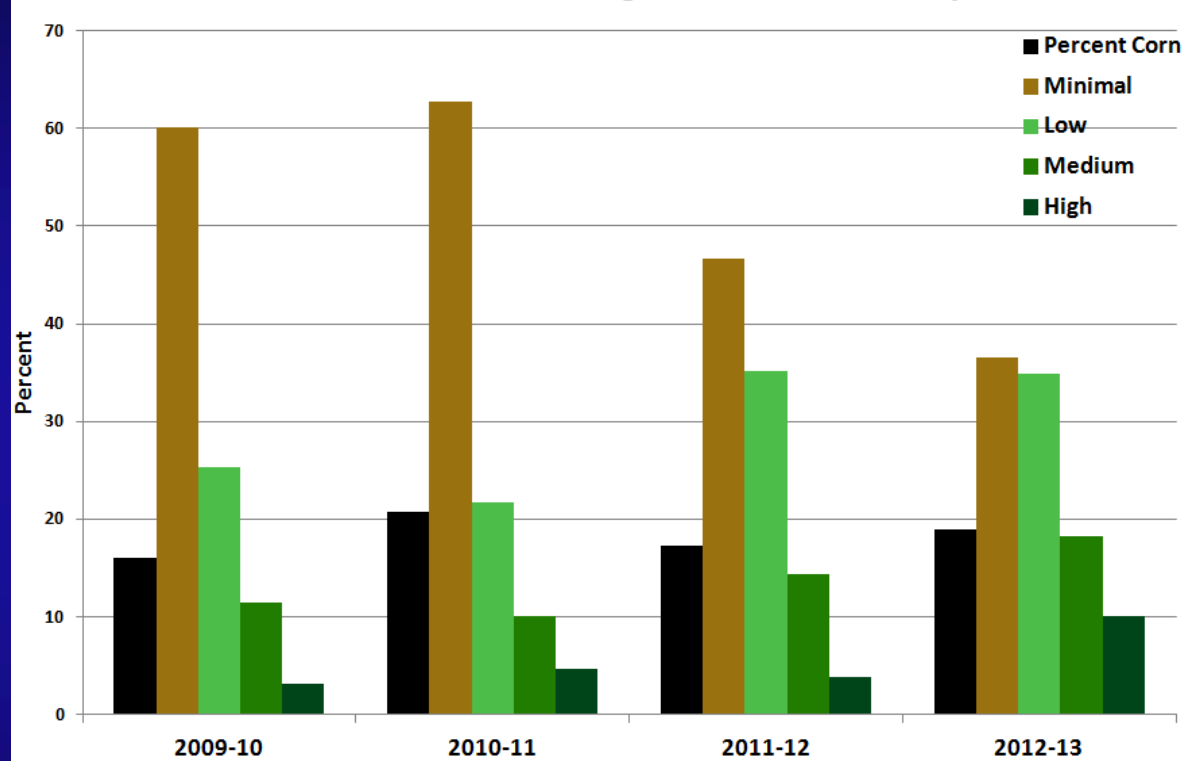
Geospatial toolkit for winter ground cover analysis

- ArcMap toolkit combine satellite imagery with cropland data to evaluate wintertime biomass on agricultural fields



Remote sensing to monitor cover crop adoption in southeastern Pennsylvania

Winter Ground Cover following Corn, Lebanon County, PA



- Identified multi-year trends in increasing use of cover crops
- Separated from effects of weather
- Results will be useful to agricultural conservation planners



0 = Minimal



1 = Low



3 = Medium



4 = High

These data are preliminary and are subject to revision

Proximal Sensors

Using on-the-go proximal sensors linked with GPS



Field samples



Crop Scan



Crop Circle



ASD

BARC Proximal Sensors Study

NDVI

- 0.14 - 0.00
- 0.00 - 0.20
- 0.20 - 0.30
- 0.30 - 0.45
- 0.45 - 0.60
- 0.60 - 0.75
- 0.75 - 1.00

BARC Field Sampling_Landsat Pixels

- Barley Sampling Points
- Wheat Sampling Points
- Triticale Sampling Points
- Rye Sampling Points

- Barley
- Wheat
- Triticale
- Ryegrass
- BareField

0 0.04 0.08 0.12 0.16 km



Work conducted at USDA-ARS
Beltsville Agricultural Research Center

Proximal Sensors



Objective:

Evaluate the effective ranges of various reflectance indices for measuring the biomass, fractional ground cover, and nitrogen content of winter small grain cover crops

Dataset:

Repeat sampling of five cover crop fields throughout the winter of 2012-13 (wheat, triticale, barley, rye, ryegrass)

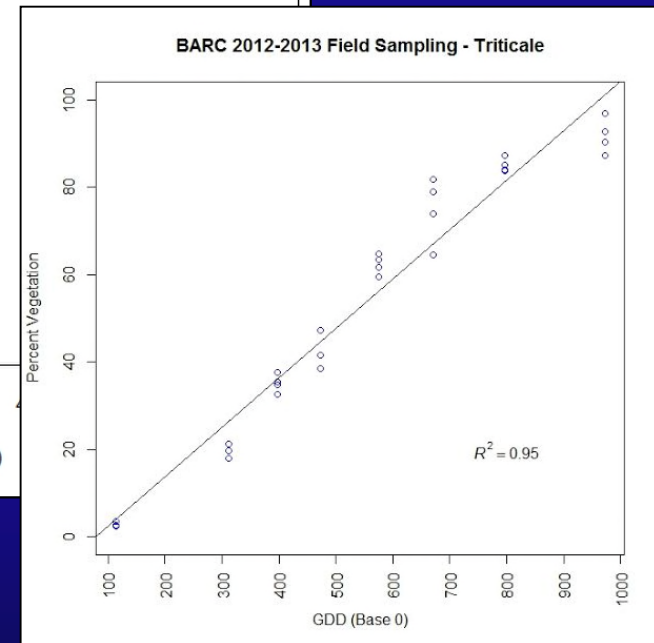
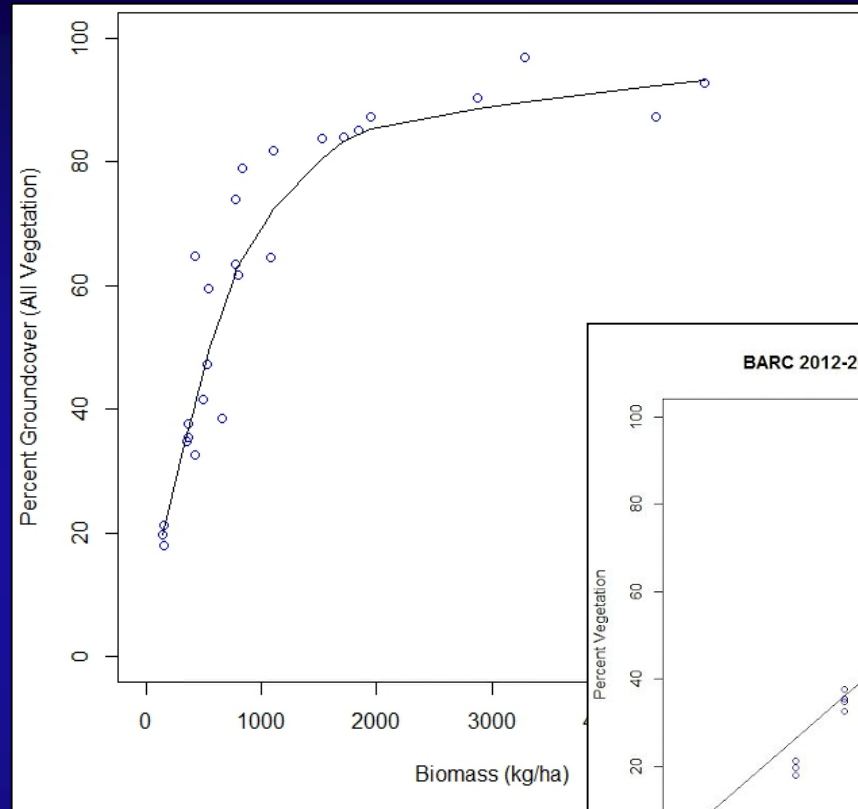
- Surface reflectance (Crop Scan, Crop Circle, ASD)
- Percent ground cover (RGB photos, Sample Point)
- Aboveground biomass, N content, soil N (lab analysis)
- Satellite imagery (Landsat, SPOT)

PhD student in Geography, Kusuma Prabhakara, is writing up the analyses for her dissertation

Proximal Sensors

Some results:

Index	Wheat1 Triticale	
	r^2	r^2
NDVI	0.970	0.890
GNDVI	0.960	0.890
SR	0.880	0.870
SAVI (L=1)	0.970	0.890
G-R	0.900	0.860
EVI	0.960	0.880
TVI	0.950	0.860
NGRD	0.920	0.920
VARI	0.920	0.920
NDREI	0.940	0.880



- Various indices are approx. equivalent in predicting biomass

- Species-specific growth curves linked to environmental endpoints

**These data are preliminary
and are subject to revision**

Outcomes

Abilities

- Satellite imagery can be used to measure vegetated ground cover and biomass, eventually nitrogen content
- In Maryland, the state cost share program is adopting a geospatial management system
- In Pennsylvania (and elsewhere in the United States) the National Cropland Data Layer can be used to determine groundcover and winter biomass by crop type

What is missing?

- Nutrient application rates and yields
- Adapt-N and farm data to predict residual soil N

Remote Sensing of Cover Crop Performance

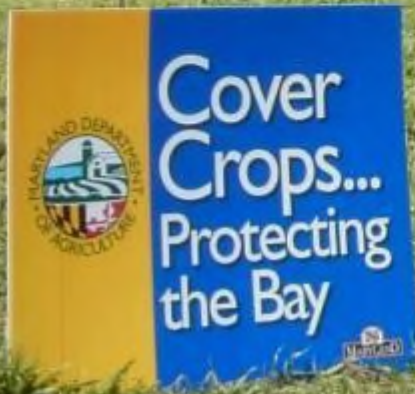
Acknowledgements:

- Thanks to Dan Jones and Kusuma Prabhakara for data processing. Antonio Pereira, Megan Parry for lab analysis, Maryland Department of Agriculture for ongoing collaboration

Funding:

- USDA-ARS Choptank River Conservation Effects Assessment Project
- National Fish and Wildlife Foundation – Innovative Nutrient and Sediment Reduction Grant Program
- USGS Priority Ecosystem Studies
- USGS Climate and Land Use Change

Thank you! ~ Questions?



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